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GEOTHERMAL FIELD AND GEOTHERMAL RESOURCES IN BELARUS

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Abstract

Results of the terrestrial temperature field studies within Belarus are briefly described. It has rather contrast pattern in the upper part of the platform cover both within Paleozoic depressions, and the Precambrian crustal blocks. A map of temperature distribution at the depth of 200 meters illustrates the main field features. The density of geothermal resources was estimated for the most promising Pripyat Trough. In result the whole area of the Pripyat Trough, and especially its northern and partially central zones, as well as the eastern part of the Podlaska-Brest Depression are considered to be the most perspective areas in Belarus for the geothermal energy utilization. For instance, the temperature of 50 ^{o}C was registered in some boreholes at the depth less than 2 km and its values above 90 ^{o}C were observed at the depth less than 4 km in the northern zone of the trough. Warm brines were found everywhere within the Pripyat Trough to the south of the line crossing Gomel, Slutsk towns till the Belarus-Ukrainian border and Slutsk, Starobin, Zhitkovichi, Stolin towns in its western.

The Byelorussian part of the Podlaska-Brest Depression is another area, representing the interest to construct a pilot geothermal plant here mostly for heating purposes. The density of geothermal energy resources varies in a wide range on average from 0.5 till 2-4 t.o.e/m^2 in the northern part of the Pripyat Trough. Colder crustal blocks exist in the rest part of the country and their geothermal potential is lower.

Introduction

Geological structures of different age, origin and evolution comprise the crust within Belarus. The territory of the country is irregularly studied by deep drilling. Temperature-depth diagrams of different quality were analyzed to study the main features of the terrestrial temperature field of the country. The Pripyat Trough nowadays belongs to the best-studied in geothermal respect, both in terrestrial temperature and heat flow density distributions. Hundreds of deep boreholes were drilled here in the course of oil prospecting works. At the same time, for instance, the territory of the Orsha Depression and especially its northern part is poor studied until now. Only a few deep boreholes were drilled into the uppermost horizons of the crystalline basement it its central part. The main massif of available temperature logs was recorded mostly in shallow boreholes, usually drilled for fresh water supply for towns and settlements. The same concerns the vast territory, occupied by the Belarussian Anteclise.

The very first information on the temperature distribution in deep horizons of the sedimentary cover was published as early as in the middle of fifties of the past century. (Belyakov, 1954) for the Pripyat Trough and the first data on the temperature pattern of the area, as well as the first heat flow density estimates were published in a few years later (Protasenya, 1962_a and 1962_b). D. Protasenya was the first who revealed a positive terrestrial temperature anomaly within the northern part of the Pripyat Trough. Its lateral extent and more accurate information on its margins were outlined by subsequent investigations (Bogomolov, et al., 1972; Atroshchenko, 1975). Later investigations showed a sufficient heterogeneity of the heat flow pattern within the whole sedimentary cover of the trough (Tsybulya, Levashkevich, 1990; Zhuk, et al., 2004). Terrestrial temperature field within the Brest and Orsha depressions remained poor studied until the recent time, though its heterogeneity was indicated by previous investigations (Tsybulya, et. Al., 1988; Zhuk, et al., 1989; Zui, 2004).

Temperature distribution map for the depth of 200 m

The lack of temperature-depth profiles for deep boreholes didn't allow preparing the detailed temperature distribution maps for horizons deeper than 400-500 meters for the whole territory of the country. Such situation exists until now. To be able to describe the main terrestrial temperature field for all geologic structures of Belarus, we compiled its map for the depth of 200 meters using practically all available data, Fig.1. Around 320 temperature-depth profiles accumulated by the author and his colleagues during the last 30- 40 years for the whole territory of the country both for shallow (50-250 meters) and deep boreholes were used to construct this map. Only around 10 diagrams of the standard logging were added after their careful selection for those boreholes, where it was believed that enough time elapsed after the drilling was finished and temperature measurements started, in other words, when the temperature equilibrium between the wellbore fluid and the surrounding massifs of rocks was reached.

Fig.1. Temperature distribution map at the depth of 200 m within Belarus, °C.

Temperature isolines were drawn by means of an interpolation within the territory of Belarus and by the extrapolation outside its borders, therefor their configuration there is very preliminary one as no reliable temperature-depth diagrams were available for the territory of Poland and the Ukraine at all. We had only a few diagrams for adjoining territories of Lithuania, Latvia and Russia. The interval 0.5 °C was used to draw isolines, in the range 7-9 °C and 1 °C for the range of 9 – 14 °C, which is acceptable, keeping in mind that the thermistor thermometer, used for borehole temperature measurements, had the error of absolute temperature readings around ±0.03 °C.

In contrast to much warmer southern and westernmost parts of the considered territory, where temperature ranges from 10 to 14 °C, its central and north-eastern parts exhibit as low values as 7-9 °C. The shape of a small positive anomaly over 10 °C shown in the north-eastern part of the map within the adjoining territory of Russia is very preliminary one, as it was shown using only one available temperature diagram recorded in the borehole “Golubye Ozera” (Blue Lakes), located in the resort of the same name in the Pskov Region. A small-area anomaly with the temperature above 10 °C in the central Belarus has the meridian orientation. It is stretched from Molodechno town through Naroch Lake almost to Drukshai Lake, located at the junction of state borders of Belarus, Latvia and Lithuania. Another anomaly with the temperature below 8.5 °C within the Orsha Depression is stretched from the northeastern Belarus into Russia.

It is necessary to stress once more that it is not possible to prepare conditioned terrestrial temperature maps for deep horizons (for instance 1000 meters) using the standard approach for this whole country, as the number of deep boreholes drilled through the whole sedimentary cover is still very limited within the northern and north-eastern parts of the Belarussian Anteclise, the western slope of the Voronezh Anteclise and Orsha Depression.

Density of Geothermal Resources

The density of geothermal resources were studied for the so-called Intersalt Complex, the Upper Salt thickness and the Devonian sediments, overlying the Upper Salt for the Pripyat Trough, which is better studied in geothermal respect than other geologic units of Belarus. The density of geothermal resources of the Intersalt Complex was estimated using the equations (1)-(4) (see Hurter, Haenel, 2002). It was based on the temperature distribution at the roof of this complex, shown in Fig. 2. Though we will not interpret this map in details, we demonstrate it only to show main features of the terrestrial temperature field of the Pripyat Trough, namely the temperature values increase when we proceed from southern and western parts of the trough to its northern limiting fault. The temperature ranges here from 30-35 to 60-65 ˚C, i.e. it increases almost twice. The salt tectonics produces here a number of local anomalies, representing its another peculiarity.

Fig. 2. Temperature distribution at the roof of the Intersalt Complex for the Pripyat Trough (compiled by V. Zui and D. Mikulchik, 2005).

When calculating the density of geothermal resources, the specific capacity of the rock matrix and warm water/brines was accepted to be $2.76 \cdot 10^6$ and $4.18 \cdot 10^6$ J/($m^3 \cdot$ ˚C), respectively. The averaged porosity was accepted to be 5%. The temperature 11 ˚C of reinjected water/brines is accepted like it is used at the Klaipeda Geothermal Plant, as the geologic conditions of the Pripyat Trough are similar to those existing in the central part of the Baltic Syneclise. The resulting data in Joules were recalculated into tons of oil equivalent (t.o.e.) using the coefficient

k = . $0.034 \cdot 10^{-9}$ t.o.e./J, (Dyadkin et al., 1991, p.170). In other words, to produce 1 J of heat it is necessary to use $0.034 \cdot 10^{-9}$ t.o.e. The map of the density of geothermal resources in t.o.e/m^2 is shown in Fig.3.

Fig. 3: Density of geothermal resources of the Intersalt Complex within the Pripyat Trough. Isolines are in t.o.e./m^2 (Zui, Mikulchik, 2005). Dots show the position of studied boreholes.

The location of some towns and settlements at the map indicates possible consumers of geothermal energy and their relation to areas with different density of geothermal resources.

The distribution of studied boreholes is not regular within the trough. Most of them correspond to the northern and partly the central parts of this unit. As it was indicated above, sparse boreholes were studied in its western part within the Turov and Starobin depressions, as well as within its southeastern part, stretched along the Bragin-Love Salient. In result, the pattern of the drawn isolines could be considered there as a preliminary one.

The density of geothermal resources within the whole area of the trough varies in a wide range from 0.112 till 1.75 t.o.e./m^2 It exceeds 1.0 t.o.e./m^2 only within the northern and northeastern parts of the trough. The latter one adjoins the Bragin-Loev Salient. The isolines are oriented mainly sub-parallel to the North Pripyat Marginal Fault. It is possible to indicate three anomalies of high density of geothermal resources. Two of them are related to the Sudovitsa and Berezina local geologic structures with the density of 1.44 and 1.41 t.o.e./m^2, respectively. The third anomaly has a wider area and includes a number of local structures: Pervomaiskaya (1.27 t.o.e./m^2), Rechitsa (1.35 t.o.e./m^2), East-Pervomayskaya (1.08-1.2 t.o.e./m^2), and others.

There are a number of local structures with the density of geothermal resources ranging from 0.2 to 0.75 t.o.e./m^2. The Visha (0.26-0.49 t.o.e./m^2), Davydovka (0.28-0,75 t.o.e./m^2), Ozemlinskaya (0.65-0.71 t.o.e./m^2), Ostashkovichi (0.56-0.60 t.o.e./m^2) and others.

The isoline of 0.50 t.o.e./m^2 crosses the whole Pripyat Trough in the sub-meridional direction and subdivides it into the colder western and the warmer eastern and northeastern parts. The prevailing values of the density of geothermal resources within the trough range from 0.20 to 0.60 t.o.e./m^2, for instance the Mozyr (0.29-0.41 t.o.e./m^2), Savichskaya (0.33-0.37 t.o.e./m^2), Kopatkevichi (0.16-0.21 t.o.e./m^2), Kamenka (0.26-0.37 t.o.e./m^2) local structures.

To calculate the geothermal potential for the whole area, the Intersalt Complex was subdivided into squares 10x10 km. In this way the area of this complex was estimated to be 23125 km^2 or 23125000000 m^2. The averaged density of geothermal resources within each of squares multiplied by its area in metres square allowed to receive the geothermal potential for each of them. Summation of all squares gave the geothermal potential of the Intersalt Complex which is 3,6948E$\cdot 10^{20}$ J or 12 562 321 967 t.o.e.

Similar approach was used to compile maps for the Upper Salt thickness and the Devonian Complex, overlying the Upper Salt, which are not discussed here. It is necessary only to note, that the density of geothermal resources, accumulated within the Upper Salt Complex are 2-3 times higher, Fig.4.

Fig. 4: Density of geothermal resources of the Upper Salt Complex within the Pripyat Trough.

Legend: 1 – Towns and settlements; 2 –Areas, where the density of geothermal resources were not calculated; 3 – Main deep faults, limiting the Pripyat Trough; 4 – Isolines of the density of geothermal resources (t.o.e./m^2).

The geothermal potential represents the averaged density of geothermal resources in J/m^2 (or in t.o.e) multiplied by the area of the complex in m^2 (23125 km^2 , or 23125000000 $м^2$). In other words, it is the portion of geothermal energy within the Pripyat Trough in Joules or in t.o.e., which could be recovered by the technology existing at present time.

The density of geothermal resources varies in a wide range within each of geothermal complexes of the Pripyat Trough; therefore, their averaged values were used. The geothermal potential was calculated by multiplication of these averaged values by the area of the trough. The results are given both in Joules and in tons of oil equivalent (t.o.e.) in Table 1.

Table 1. Geothermal potential of the Pripyat Trough (Zui, D. Mikulchik, 2005).

Geothermal complex	Average density of geothermal resources, J/m^2	Geothermal potential, J
	Same, t.o.e/m^2	Same, t.o.e.
Sediments, overlying the “above-the-salt” Devonian rocks	7525735630	$1{,}74033 \cdot 10^{20}$
	0,255875011	5 917 109 639
Devonian rocks, overlying the Upper Salt	4740604961	$1{,}09626 \cdot 10^{20}$
	0,161181	3 727 310 625
Upper Salt Complex	80234404305	$1{,}85542 \cdot 10^{21}$
	2,72797	63 084 306 250
Intersalt Complex	15977516015	$3{,}6948\text{E} \cdot 10^{20}$
	0,543236	12 562 321 967

Similar investigations are undertaken now to estimate the density of geothermal resources for the eastern part of the Podlaska-Brest Depression, stretched into the territory of Belarus. Only very preliminary information is available now on the density of geothermal resources within the Orsha Depression. The same concerns the Byelorussian Anteclise adjoining saddles and inliers. The provisional estimates of the density of geothermal resources within Belarus are shown in Fig. 5.

Fig. 5: Simplified chart of the density distribution of geothermal resources within Belarus in t.o.e/m^2.

Low-enthalpy geothermal energy could be used practically within the whole territory of Belarus. But the density of geothermal resources varies in a wide range from 0.01 to maximum 4 t.o.e/m^2. Low values are typical for the main part of the Belarussian Anteclise, the adjoining Latvian, Polessian and Zhlobin Saddles. These values are slightly higher for practically the whole area of the Orsha Depression (0.05 – 0.1 t.o.e/m^2). All these areas, except the Pripyat Trough, are still sporadically studied in the sense of their geothermal potential. This work could be done in the forthcoming years.

Conclusions

The most promising geologic units for practical utilization of geothermal energy are the Pripyat Trough and the eastern part of the Podlaska-Brest Depression within the territory of Belarus. Studied geothermal horizons of the Pripyat Trough show that the density of geothermal resources varies in a wide range (on average from 0.5 to 4 t.o.e/m^2). The Intersalt Complex of the Pripyat Trough represents the interest for practical utilization of warm brines, whereas the heat from thick salt deposits could be extracted by means of borehole heat exchangers.

Geothermal conditions of the Pripyat Trough are similar to those in the western part of Lithuania, where the pilot Klaipeda Geothermal Plant was put into operation and successfully operates during a few years. Its heat capacity is 35 MW_{th}. It produces heat for Klaipeda districts two times cheaper comparing to the heat generated by standard heat boiler-houses.

The renewable geothermal energy was not used until now within the territory of the Pripyat Trough. Its northern and northeastern parts, as well as the Podlaska-Brest Depression represent the paramount interest to construct there pilot geothermal plants, which would be useful to stimulate the practical utilization of geothermal resources in the country, though the rest area of the country has the density of geothermal resources, acceptable for practical utilization, e.g. for heating of greenhouses and buildings using both vertical and horizontal heat exchangers coupled with heat pumps.

Many boreholes were drilled within the Pripyat Trough outside oil fields in the course of oil prospecting works. Dozens of them could be repaired and used to exploit the geothermal resources. Their reanimation will increase the economic feasibility of such projects.

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